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73rd MORS SYMPOSIUM
WG 15 – Air Power and Combat Identification Analysis

Rapidly delivering war-winning capability

U.S. AIR FORCE

Assessing the Mission Effectiveness of Morphing Aircraft Structures Technologies in Hunter/Killer Operations

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OUTLINE

- Introduction
- UAV Concept Definitions
- SEAS Modeling
- Results
- Conclusions

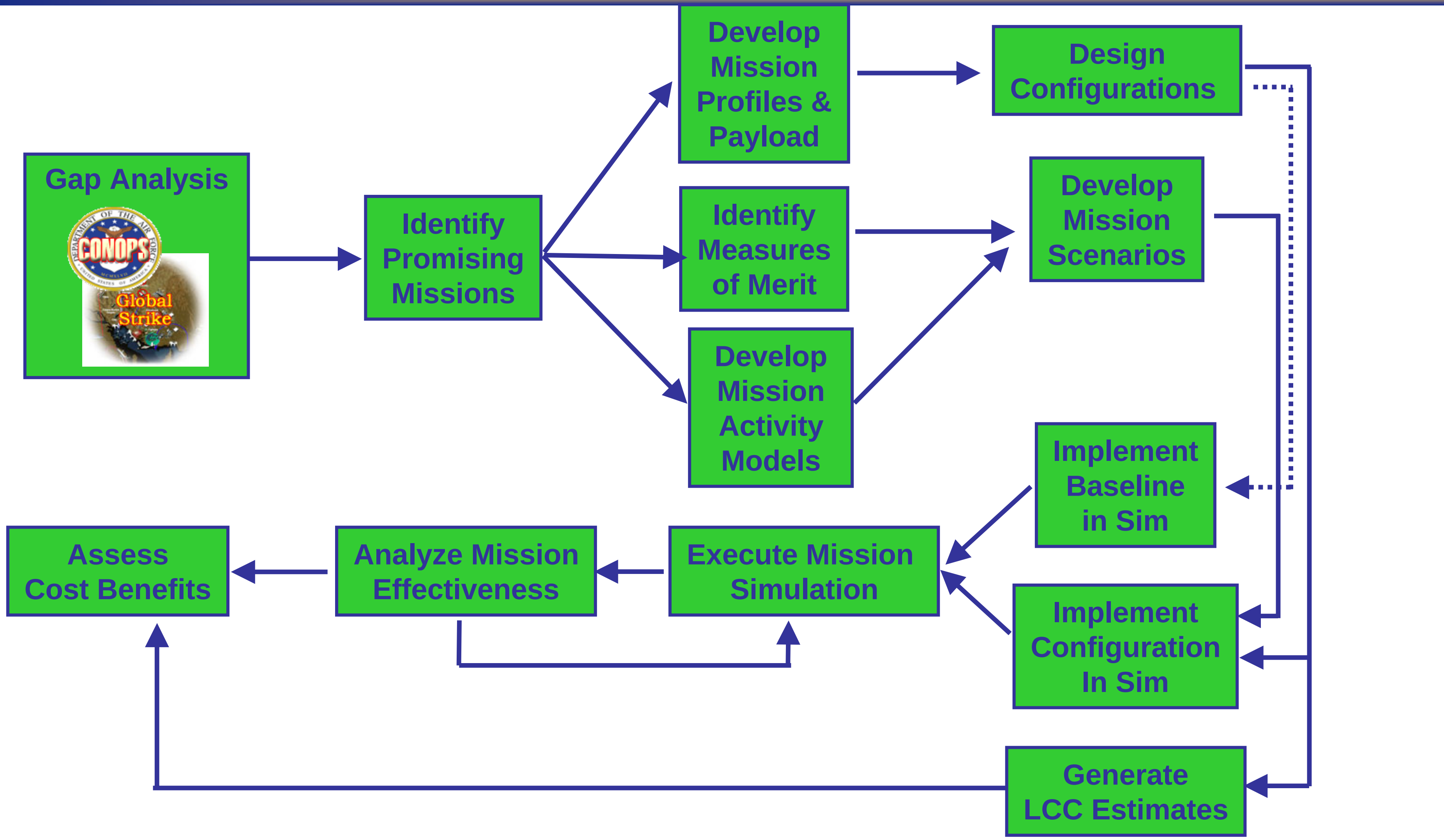
Contributing Agencies

Organization	Name	Contribution
AFRL/VAAA	Ryan Plumley	Vehicle Design
AFRL/VASA	Dr. Brian Sanders	Design Team Lead
AFRL/VASA	David Brown	Design Team Lead
ASC/XRE	David Wright	Vehicle Design
DARPA	Dr. Terry Weisshaar	DARPA Rep
General Dynamics	Chris Linhardt	Analysis Team Lead
General Dynamics	Terry Brown	Mission-Level Analysis
The Greentree Group	Frank Campanile	Cost & Technical
SAIC	Eric Martin	Mission-Level Analysis

Problem Statement

- Assess mission effectiveness of morphing technology enabled small UAVs
  - Identify promising missions taking advantage of morphing attributes
  - Identify mission profiles and sensor/avionics/ weapons (weights) packages for designers to develop configurations and performance characteristics
  - Assess comparative mission effectiveness of morphing configurations versus baseline
  - Assess cost benefit of morphing configurations

Methodology



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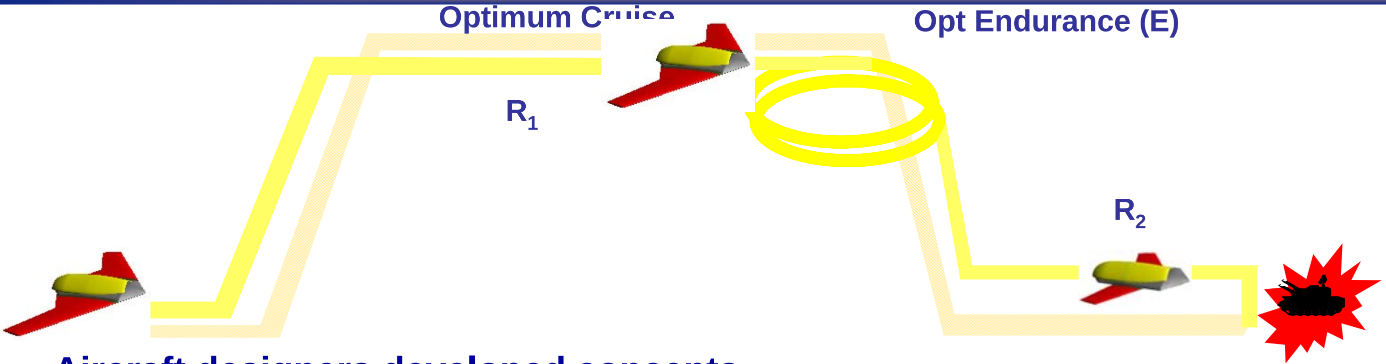
UAV Concepts Description

Concepts	Description
Out-of-Plane Morphed	UAV design with out-of-plane morphing wings. Extended during climbout, cruise and loiter. Folded when attacking ground targets
HiAR	High aspect ratio variant of Lockheed design
LoAR	Low aspect ratio variant of Lockheed design
ModAR	Optimized UAV for ground attack mission
ModAR2	Optimized UAV for ground attack mission
In-Plane Morphed	Morphing UAV (in-plane folding wings)
Predator (Hi-Lo-Lo-Hi)	Predator with hi-lo-lo-hi altitude attack profile
Predator (All Hi)	Predator with all high altitude attack profile
F16C Block 50	Block 50 F16C being italicized in ground attack mission

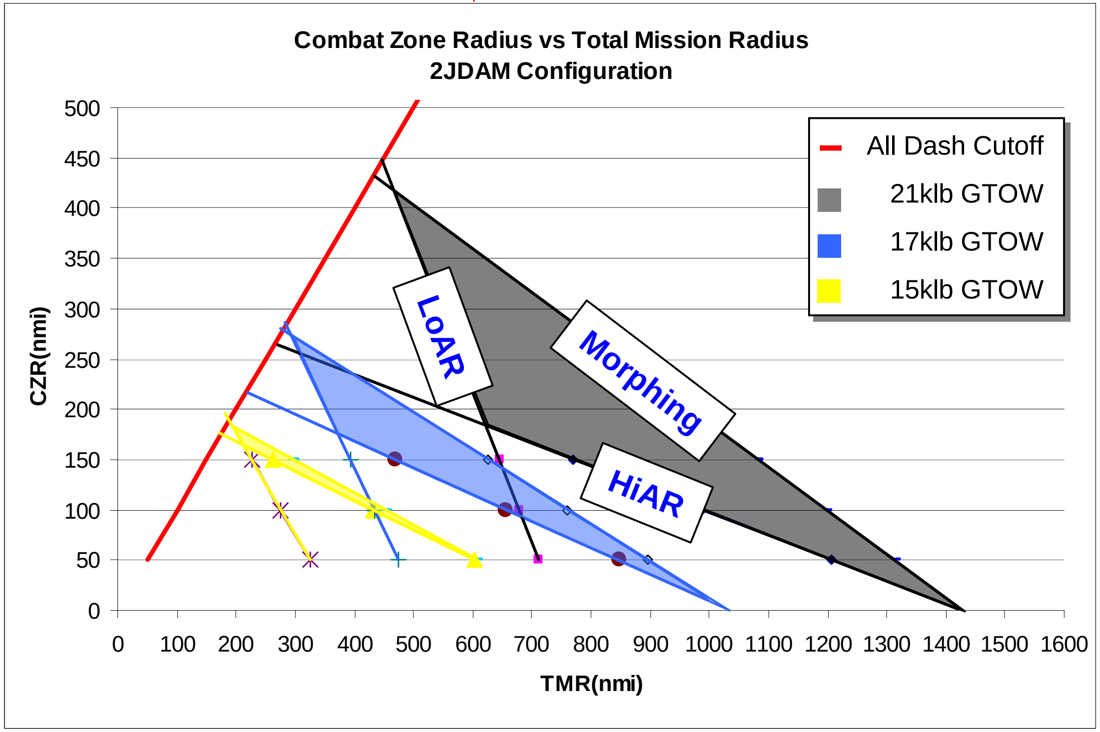
All concepts have nominal weight and size allocation for payloads, sensor suite and engine. Fuel was added to non-morphing vehicles to account for the weight of the morphing mechanism.

UAV Mission Profile



Aircraft designers developed concepts based on desired mission profile:

- **Out-of-Plane Morphed**
- **High AR**
- **Low AR**
- **Two Modified Fixed Wing (Optimized)**
- **In-plane Morphed**
- **Two Predators**
- **F16C Bl 50**



Weapons: 6 SDBs* for Predator
8 SDBs for all other concepts

*** SDB – Small Diameter Bomb (weighs approx 500lbs each) Chart on right built using 2 JDAM, the equivalent weight of 8 SDBs.**

Key Air Vehicle Parameters Used in SEAS

	Climbout		Cruise		Loiter		Dash		Fuel		
Concepts	Fuel Burn Rate	Velocity (fps)	Fuel Burn Rate	Velocity (fps)	Fuel Burn Rate	Velocity (fps)	Fuel Burn Rate	Velocity (fps)	Total Fuel (Lbs)	Available Total (Lbs)	Unavailable/ Reserves (Lbs)
OP Morphed	33.7	732.9	13.8	732.9	13.8	732.9	51.5	947.8	5583	5174	409
HiAR	25.0	729.9	12.8	729.9	12.8	729.9	61.2	898.7	5859	5472	387
LoAR	52.6	850.3	29.0	850.3	29.0	850.3	52.5	945.6	5859	5309	550
ModAR	39.0	646.7	13.1	646.7	11.6	573.4	57.0	886.1	5076	4486	590
ModAR2	26.3	635.5	12.1	635.5	10.4	565.5	52.6	892.2	5799	5247	552
IN Morphed	27.7	690.2	13.5	711.7	10.0	641.4	61.1	978.8	4485	4081	404
Predhllh	6.6	280.0	4.4	322.0	6.4	255.0	6.0	503.0	4000	3800	200
PredAllhi	6.6	295.0	4.5	215.0	4.7	330.0	6.0	503.0	4000	3800	200
F16BL50	142.42	833.8	61.3	822.8	61.3	822.8	225.6	1004.5	12194	10773	1421

Efficiency of the concepts throughout the operating regime of the mission profiles drove effectiveness and cost benefits

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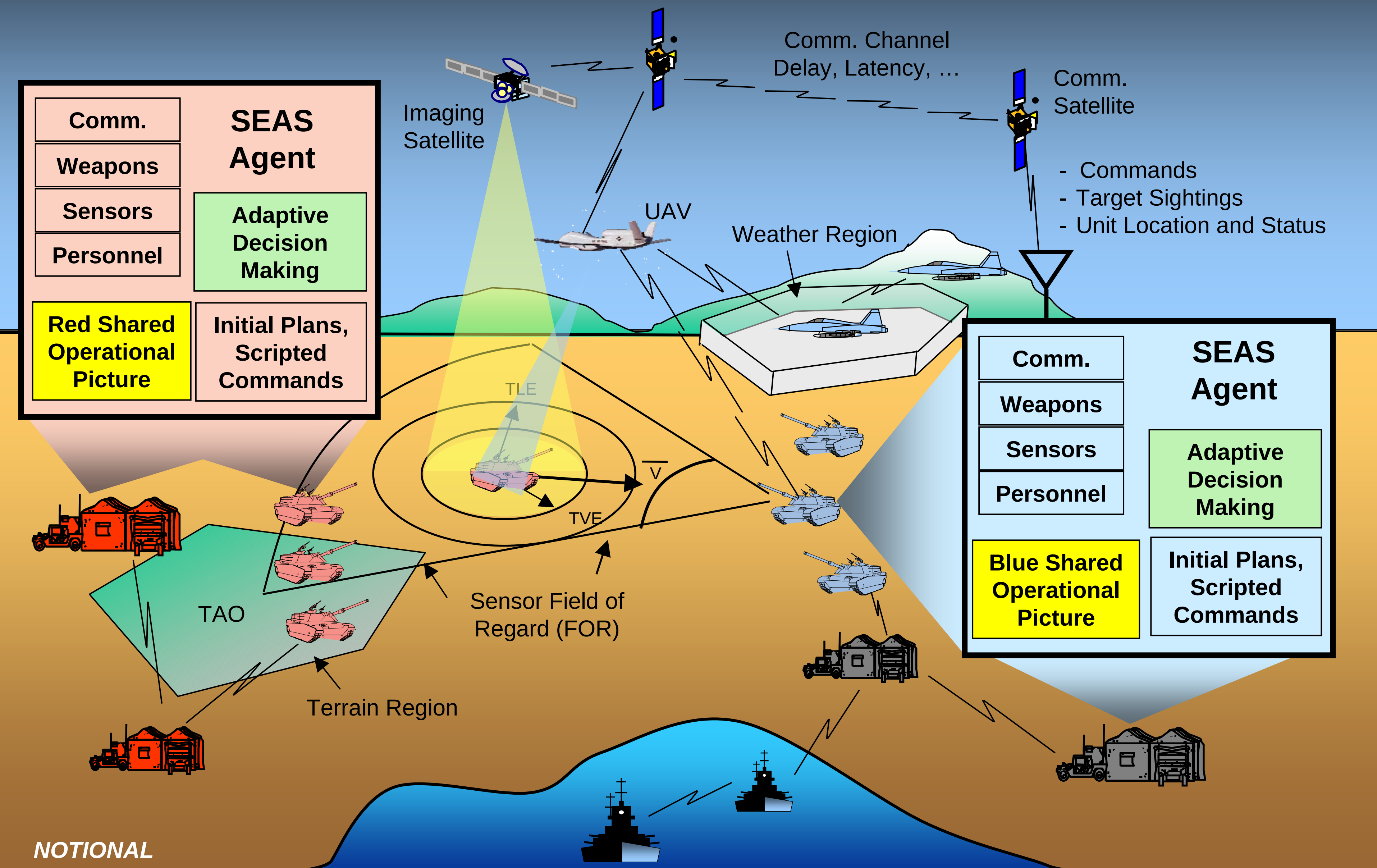
System Effectiveness Analysis Simulations (SEAS)

- Designed from the ground-up as a Quick Reaction Analysis (QRA) tool for exploring the sensitivity of space services to military utility
  - Rapid development and modification of tactics and behaviors
- AF M&S Toolset
- SEAS treats combat as a multi-agent system
  - Captures the non-linear behavior involved in real-world operations
  - Explicitly models the sensor-to-shooter chain

The SEAS Simulated Environment



Trade Space Inputs

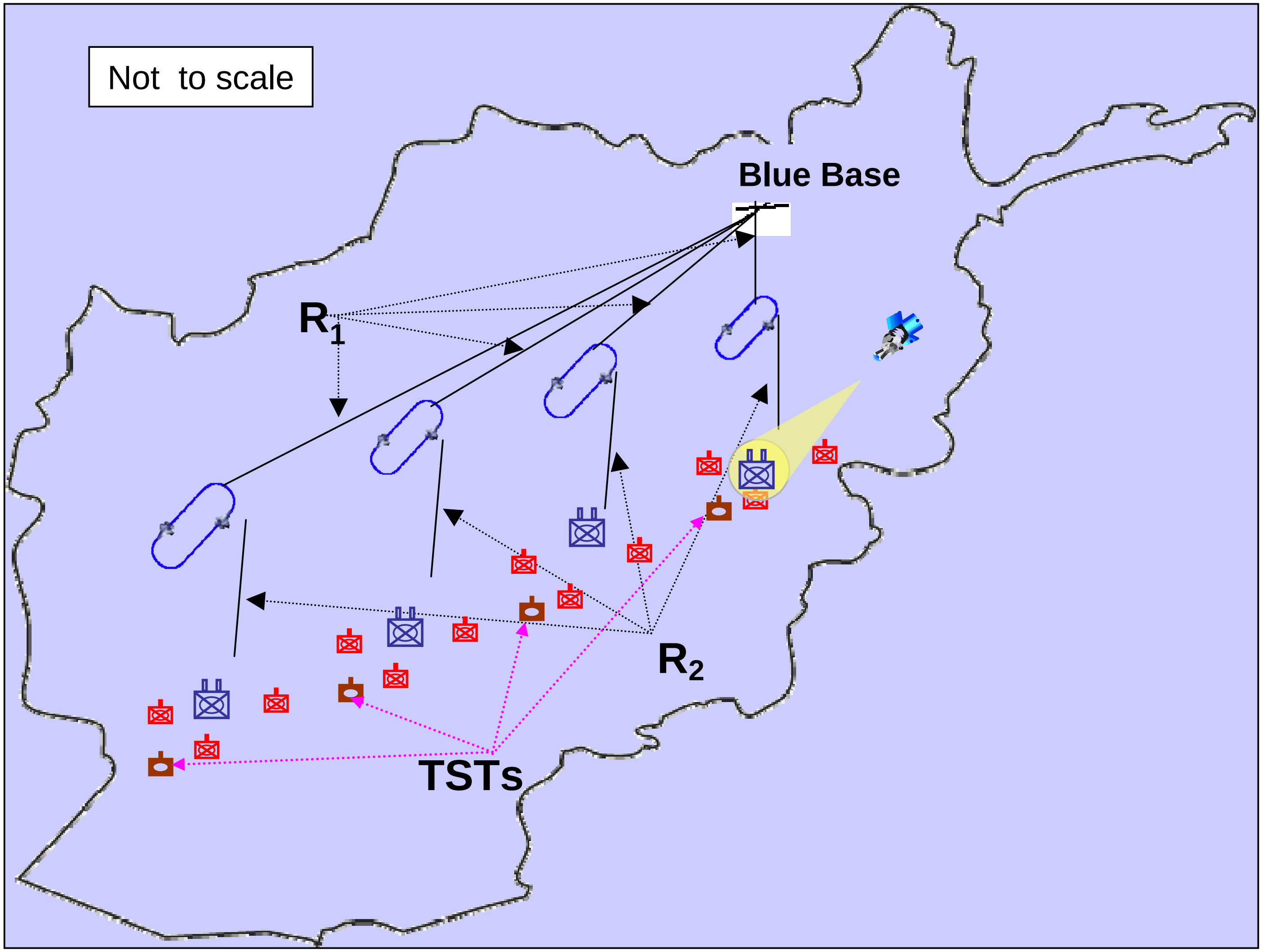
INPUTS	VARIABLES
Concepts under Study	• Out-of-Plane Morphed • HiAR • LoAR • ModAR • ModAR2 • In-Plane Morphed • Predator (Hi-Lo-Lo-Hi) • Predator (Hi-Hi) • F16C Bl 50
Target Set	• Baseline Set (14 red trucks and 23 red soldier clusters) • TST + baseline • Increased Baseline Set by 8 trucks and 6 red soldier clusters
Distance from Blue base to Loitering Point 1 (R_1)	• Short (~30 NM) • Medium (~80 NM) • Long (~125 NM) • Very Long (~200 NM)
Distance to Targets from Loitering Point 2 (R_2)	• ~45 NM • ~75 NM
Loiter/Dash Percentages for Morphed Vehicle	• 52%/38% • 44%/44%

Measures of Merit

- **SEAS**
  - Number of sorties over 24-hours period
  - Blue Kills: Baseline targets (red trucks and red soldiers) and TST targets killed
  - Number of blue soldiers surviving (total of 50 in units)
  - Kills Per UAV
  - Shots Per Kills
  - Number of missiles fired
  - Number of dashes to targets
  - Sortie Times
  - Composite
- **Others**
  - Fleet Size
  - Cost Estimate

Selected MOMs to characterize effectiveness of small UAVs in operational environment

Modeled Scenario
Killbox Interdiction



Scenario Description
- 24 hour duration
- Taliban forces (mounted and dismounted) collect and move against US Forces
- Blue ISR detect Taliban forces and provide intelligence
- Hunter/Killer Concepts assigned targets

Hunter/Killer Behavior
- Fly to loiter orbit location
- Multiple aircraft cycled to maintain 24/7 presence @ loiter
- Receive target cue and initiates attack profile @ dash
- Detects, identifies, engages, and BDA
- Return to orbit
- RTB when bingo fuel or Winchester weapons

Concept performance changes (fuel burn rate, altitude and speed) with phases (climbout, cruise, loiter, dash)

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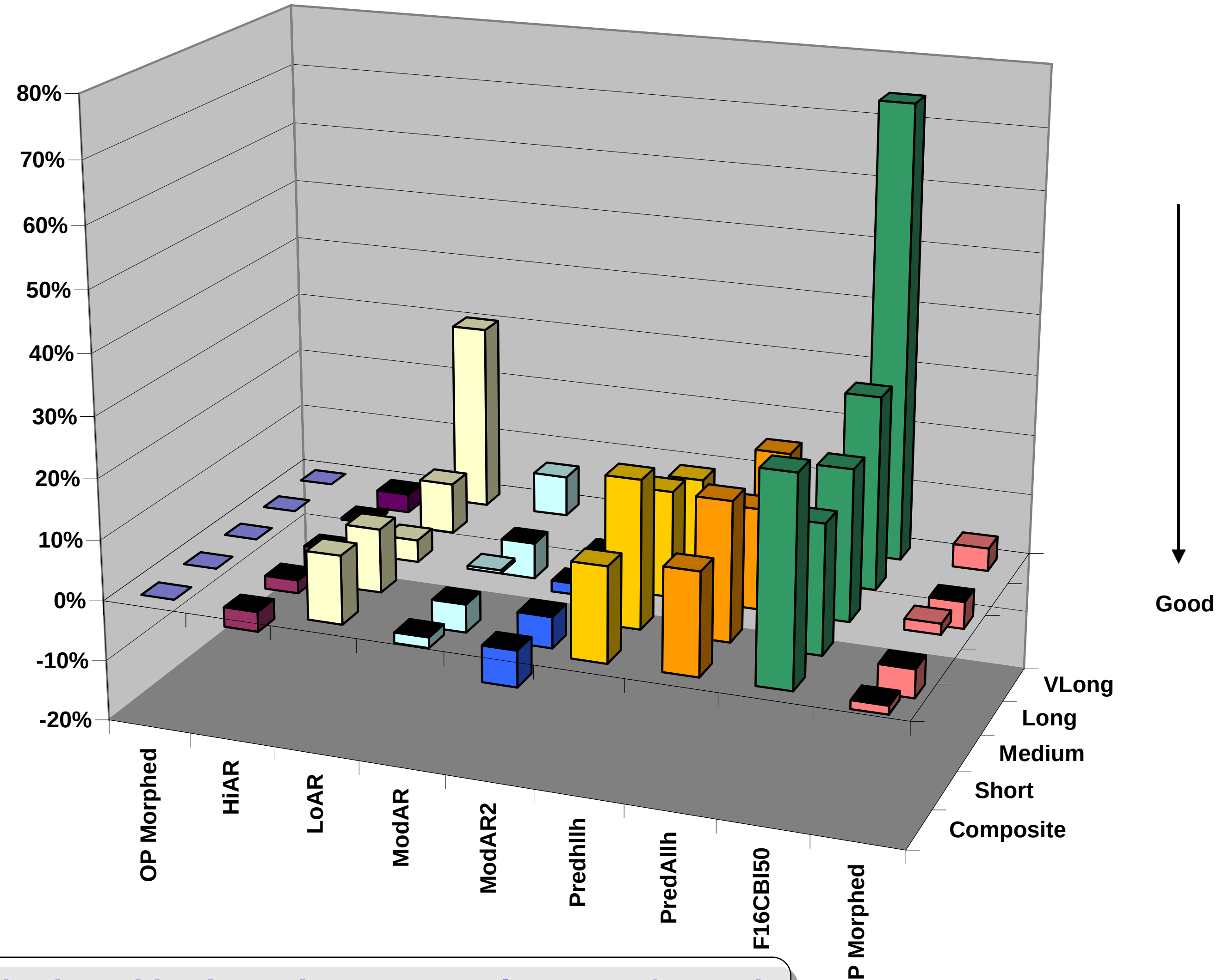
Sorties Used
(Data Normalized to Out-of-Plane Morphed UAV)

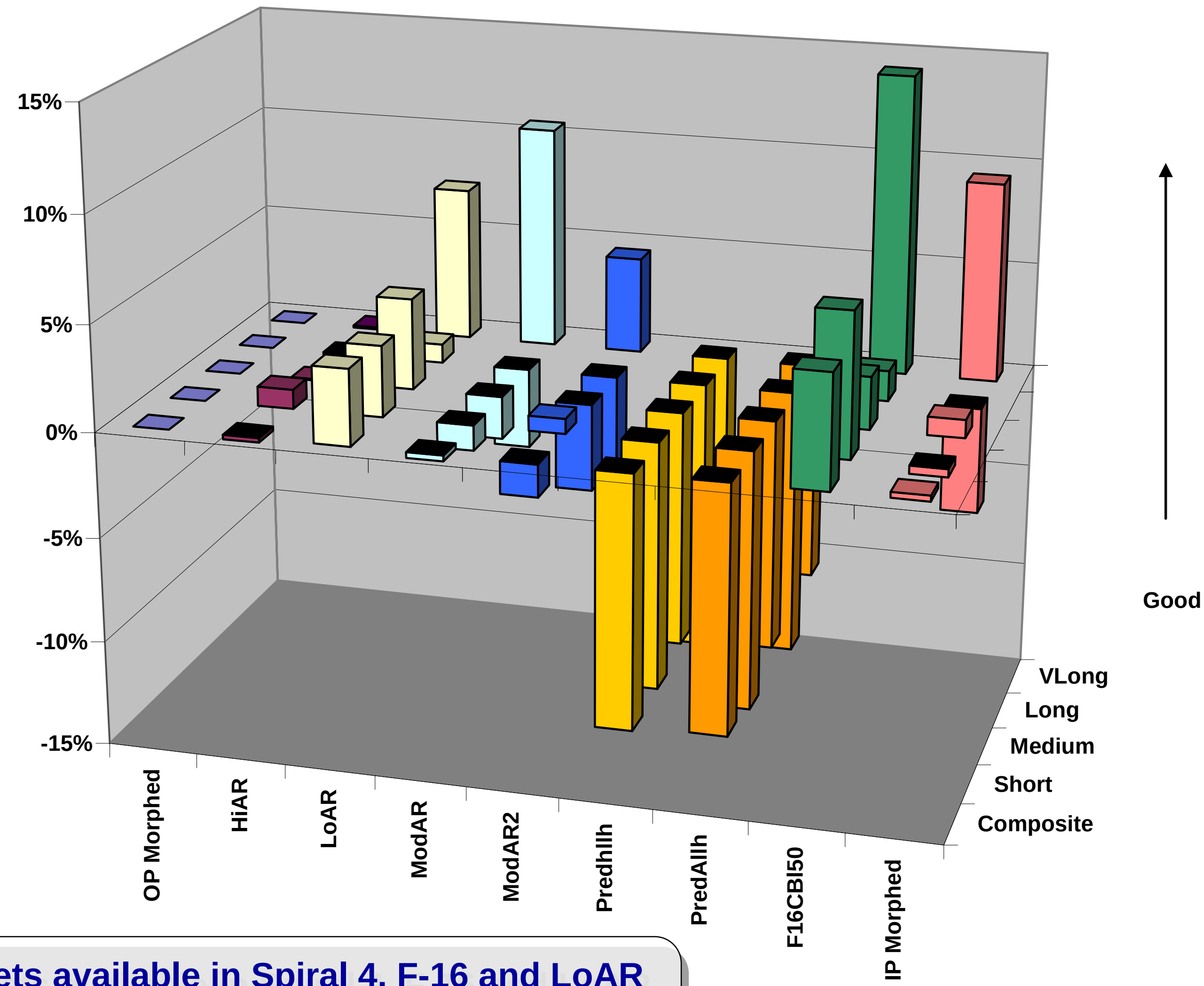
Spiral 4
R2~75 NM
Loiter/Dash 44%/44%



HiAR, IP Morphed, and both ModARs narrowly outperformed Out-of-Plane Morphed UAV.

Targets Killed by Blue
(Data Normalized to Out-of-Plane Morphed UAV)

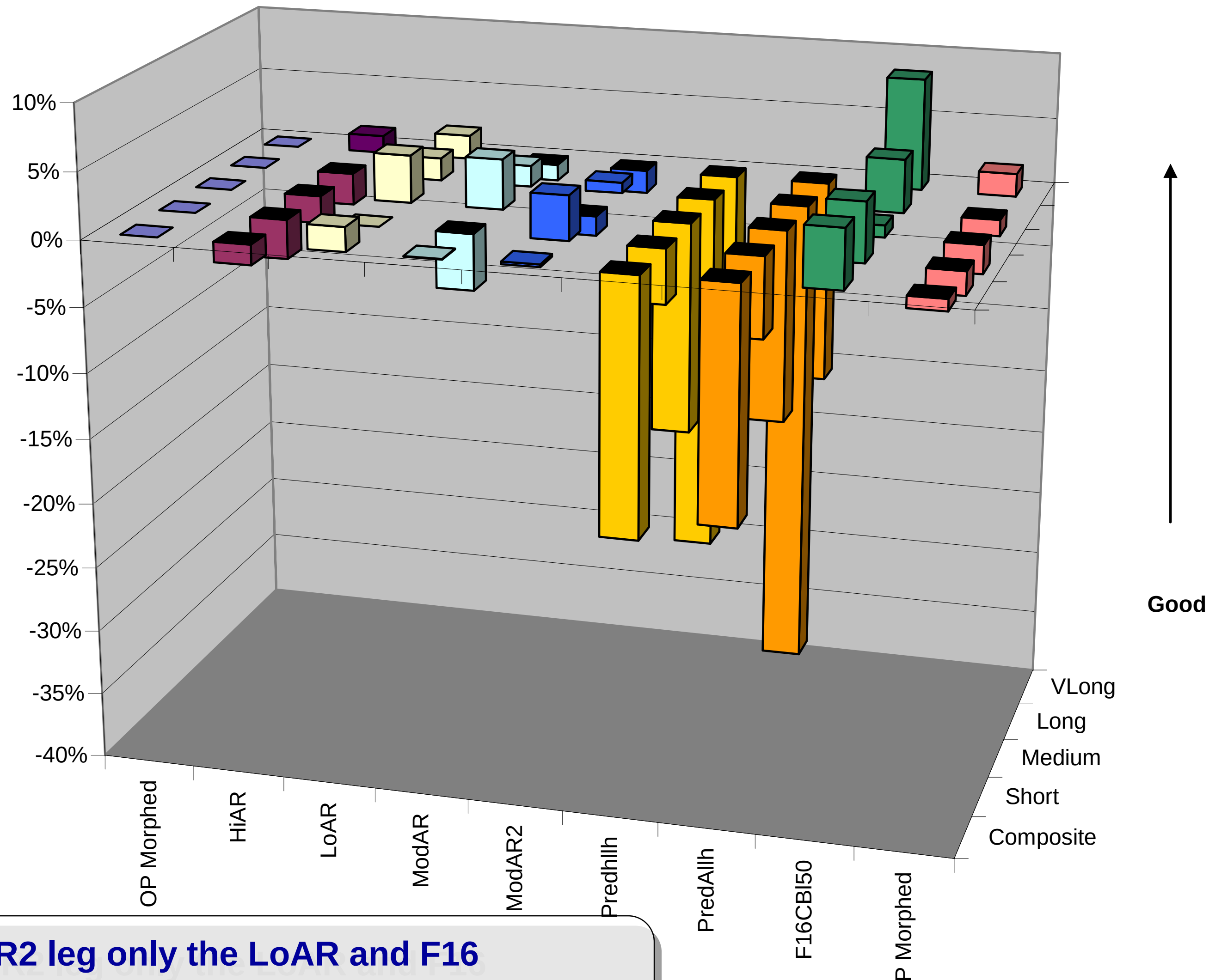
Spiral 4
R2~75 NM
Loiter/Dash 44%/44%



With more targets available in Spiral 4, F-16 and LoAR outperformed the rest. Predators have difficulty getting to TSTs.

Blue Alive
(Data Normalized to Out-of-Plane Morphed UAV)

Spiral 4
R2~75 NM
Loiter/Dash 44%/44%



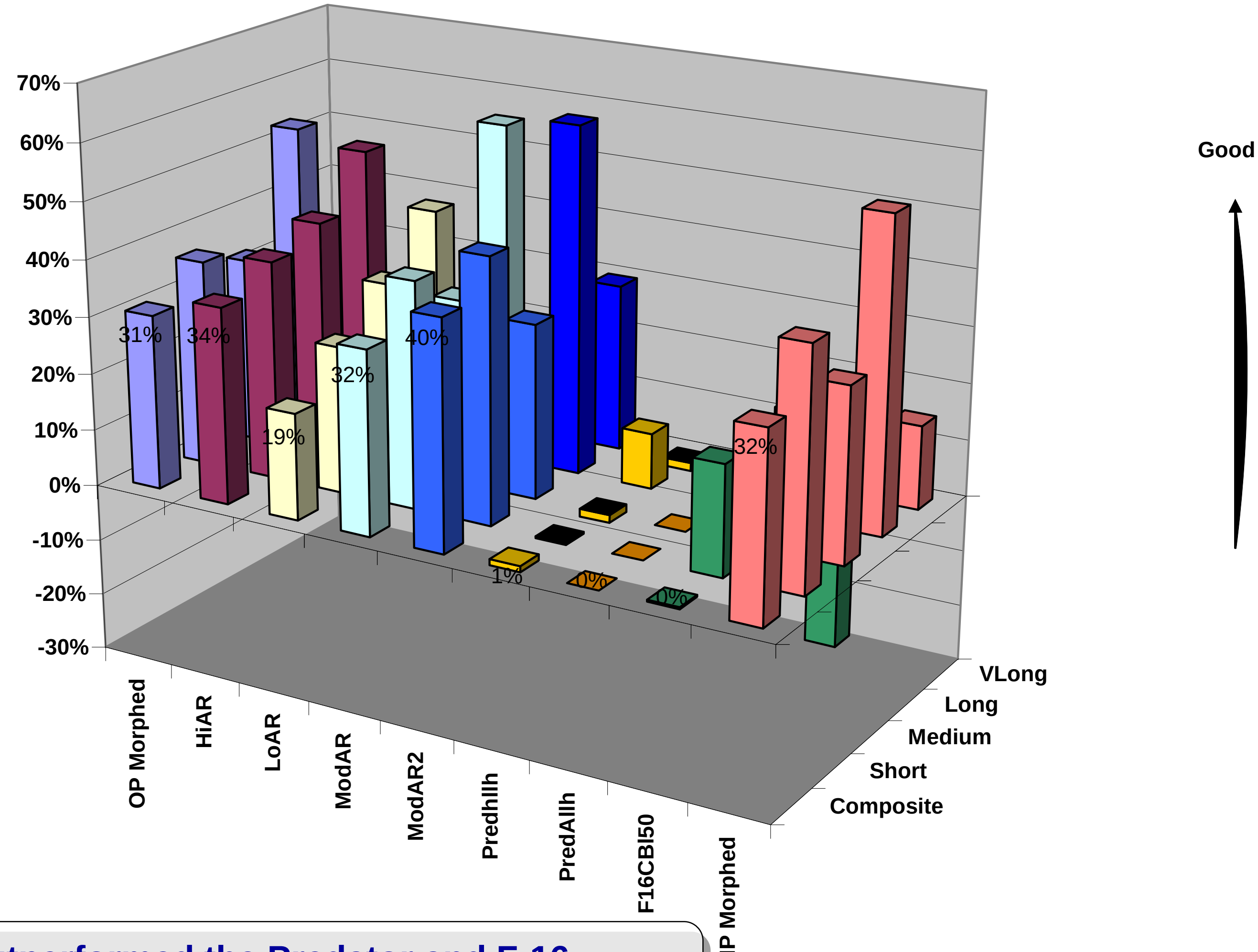
With the longer R2 leg only the LoAR and F16 outperformed OP Morphed across all mission lengths in protecting Blue ground forces.

Composite Score

Percent Improvement

Composite Score = (Total Blue Kills + Blue Alive)/Sorties Flown

% Improvement over the Predator All Hi Configuration



All the UAVs outperformed the Predator and F-16.
ModAR2 has slight edge among the UAVs.

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CONCLUSIONS

- A new small UAV provides substantial improvement to mission effectiveness as compared to fielded systems
- Morphing vehicles performed well across missions profiles that have been addressed
  - Morphing vehicles provide flexibility and responsiveness across mission profiles
- Fixed wings UAVs did outperformed morphing on several key measures. Differences were attributed to tailored concepts design to the mission profile and weight penalty
- SEAS model enable team to characterize UAV concepts to assess the merits of morphing concepts. Model showed sensitivity to:
  - Key A/V inputs to SEAS (fuel burn rates and speeds).
  - Varying the R1 and R2 legs of the mission

THE END